PROJECT REPORT FORM

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*Notebook 659,
pages 145-159

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pages 6-15, 17,
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46

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EVALUATION OF POLYETHYLENE AS A STRAIN SHEET FOR THE EXTENSIBILITY TESTER

INTRODUCTION

The low temperature characteristics of waxes and asphalts are of great interest to the producers and consumers of these materials.

The low temperature extensibility of waxes and asphalts is of particular interest for military purposes. (See Project 1150, Progress Report Two, page 9.) The Institute of Paper Chemistry has done considerable work on such materials and has played an important part in the development of instruments for testing this property.

The first instrumental development was the pendulum-type tester for flexibility of waxes. (See Institute of Paper Chemistry Research Bulletin 9, no. 4, pages 112-114 (1942-1943) and Project 1150, Progress Report Two, pages 9-11). Its usefulness was limited to waxes as it could not be applied satisfactorily to the case of materials like asphalt due to the tendency for the specimens to break at the point of impact at low temperatures instead of at the theoretical point of maximum moment. (Project 1150, Progress Report Two, page 11; Project 1123, page 10 of Report dated October 16, 1945; Project 1123, Project Report dated May 12, 1945.) The second development was an extensibility tester based upon the principle of a trapezoidal strain sheet which is stretched to different extents along its length when pulled at one end. Any coating of wax or asphalt would crack in the area where the extensibility is exceeded. The first model was actuated by the force of a falling weight. This model was limited as to the possible range in the rate of testing. Since asphalts were found to exhibit brittleness which increased with the rate of testing a second model incorporating a motorized drive was designed and built with the expectation of investigating the effect of rate of testing. This instrument served to indicate that the strain sheets originally selected were too low in modulus of stretching since the coating being tested appeared to affect the calibration of the strain sheet.

This report covers the evaluation of polyethylene as a strain sheet for low temperature extensibility testing of asphalt. According to previous work it appeared as though the extensibility value for a given asphalt was greater with a lower modulus strain sheet. This effect was checked by comparing polyethylene (Bakelite DS 3462) with Rainbow gasket material (U. S. Rubber) which previously had been found to be least affected in calibration and to have the highest modulus of the materials submitted. (See Project 1220-10-1, Report 2, page 10).

PROCEDURE

SPECIMEN PREPARATION

Strain sheets were cut in the usual trapezoidal shape 7 3/8 inches long and 3 inches wide at one end and 7/8 inch wide at the other end.

The strain sheets were coated with asphalt (Standard Oil Company of Indiana - Korite) using the Martinson coater. The strain sheets were preheated with infrared lamps. The asphalt was melted at 120° C. and the Martinson knife was held at 150° C. A paper mask was cut so that the entire width of the strain sheet was coated. The area which fits under the jaws of the extensibility tester was protected with masking tape.

The coating thickness was varied in order to determine the effect of the thickness of the coating on the strain sheet. The thickness was checked with a Cady dial type micrometer by protecting the asphalt with PT cellophane (E. I. du Pont de Nemours & Company, Inc.).

The stress-strain curves for the polyethylene sheet and the Rainbow gasket material were obtained at different temperatures. For room temperature results the Baldwin Southwark universal tester was used and the curves obtained directly.

For the low temperature results a special screw driven by an electric motor was used. The force required to extend the specimen was measured with a small Dillon gage by mounting it on a smooth glass surface between the screw and the push rod. The spring at the end of the push rod was removed to hold the speed of stretching constant.

The specimens were cut to a one-inch width and the extension measured with an extensometer mounted on the specimen.

The hardness of the two materials was tested with both a Shore Durometer "A" and Durometer "D."

TESTING

The extensibility tester was placed inside an insulated box lined with refrigerating coils cooled with a Freon-12 filled compressor unit. The temperature was controlled by a pressure-type regulator.

The asphalt-coated specimens were placed on shelves in the box and allowed to condition for at least one day. The specimens were handled with tongs to minimize locallized heating while being moved into position on the tester.

The strain sheets were supported on a small brass table which also served to locate the clamps in the loading position. After the cam-actuated clamps were closed the slack produced in the strain sheet was removed by adjusting the position of the zero adjustment bar.

The speed of testing was determined by the pulley arrangement used for the drive. The range of extension was determined by the position of the strain sheet along the actuating lever. The high position gave the greatest extension. The amount of movement was tested with a dial micrometer and it was found that a 0.508 inch movement at the push rod gave 0.286 inch movement at the "high" range, 0.195 inch at the "middle" range and 0.089 inch at the low range.

Since it had been established by previous work that each type of strain sheet material will have its own calibration curve no attempt was made at this time to calibrate the strain sheets. However, since it has also been shown that the weaker strain sheets gave an apparently higher extensibility value for the asphalt coating it appeared sufficient to establish whether the polyethylene strain sheet gives a lower relative extensibility for a given asphalt than does the Rainbow gasket strain sheet. This was determined by observing the distance from the wide end of the strain sheet to the nearest crack which results in the asphalt on stretching the strain sheet quickly. The cracks were made more visible by dusting the strained specimen with talc.

RESULTS AND DISCUSSION

The results for the comparison of polyethylene and Rainbow gasket material as strain sheets are shown in Table I.

The polyethylene strain sheet appeared to give the "Korite" asphalt a higher extensibility than did the Rainbow gasket strain sheet. This is not in keeping with the previous indications that a higher modulus material gave a lower apparent extensibility value.

Tests on the spring at the end of the push rod showed that a force of approximately 60 pounds compressed it from 0.376 inch to 0.255 inch. This would mean that the actual rate of extension of a higher modulus strain sheet is not as great as the theoretical value. The theoretical value was postulated on the assumption that no compression of the spring will take place until the end of the lever movement has been reached. (See Project 1195, Progress Report Twelve, page 9.) Without further information it would be difficult to predict how greatly the compression of this spring does affect the results. This may be one reason for the increase in acceleration reported in Project 1195, Termination Report on page 30.

TABLE I

COMPARISON OF POLYETHYLENE AND RAINBOW GASKET STRAIN SHEETS

A. Rainbow gasket (.061 inch thick). Coated with "Korite" asphalt.

Sample No.	Temperature, °F.	Asphalt Thickness, inches	Range	Time, seconds	Distance to first crack, inches
659-146-1	7.0	.0015	High	0.1	no cracks
659-146-5	6.5	.0045	High	0.1	1.69
659-146-4	6.5	.0075	High	0.1	2.44
659-146-3	5.5	.0090	High	0.1	1.47
659-146-2	7.0	.0120	High	0.1	2.88

B. Polyethylene (.060 inch thick). Coated with "Korite" asphalt.

Sample No.	Temperature, °F.	Asphalt Thickness, inches	Range	Time, seconds	Distance to first crack, inches
659-146-6	8.0	.0075	High	0.1	4.00
659-146-7	7.0	.0085	High	0.1	5.28
659-146-9	6.0	.0090	High	0.1	4.06
659-148-0	5.0	.0100	High	0.1	3.19
659-146-10	6.0	.0115	High	0.1	3.50
659-146-8	5.2	.0120	High	0.1	slips in small chuck

Note: Cold box set for 5° F.

There appears to be a minimum extensibility with a coating thickness of about 10 mils. A very thin coating is apparently able to stand a greater extension than a thicker coating. This is shown by the lack of cracks in sample 659-146-1 in Table I. Previous work with wax gave similar results. (See Project 1150, Progress Report Three, Packaging with Plastics, August 3, 1945, pages 16-17.)

At -18.5 ± 2.5° F. the results are somewhat subjective due to the difficulty encountered in locating the exceedingly fine cracks in the asphalt. The usual dusting with talc was not of much help as the talc did not go down into the fine cracks which were produced. One polyethylene strain sheet broke at this temperature while using the middle range. The results are shown in Table II.

TABLE II

EFFECT OF ASPHALT THICKNESS ON POLYETHYLENE STRAIN SHEET AT LOWER TEMPERATURES

Sample No.	Temperature, °F.	Asphalt Thickness, inches	Distance to first crack, inches
659-148-6	-16	.0065	6.25
659-148-2	-18	.0085	5.88
659-148-1	-21	.0085	cracks too fine
659-148-5	-18	.0085	strain sheet broke
659-148-3	-18	.0105	3.31
659-148-3a	-21	.0130	5.94

Range: Middle

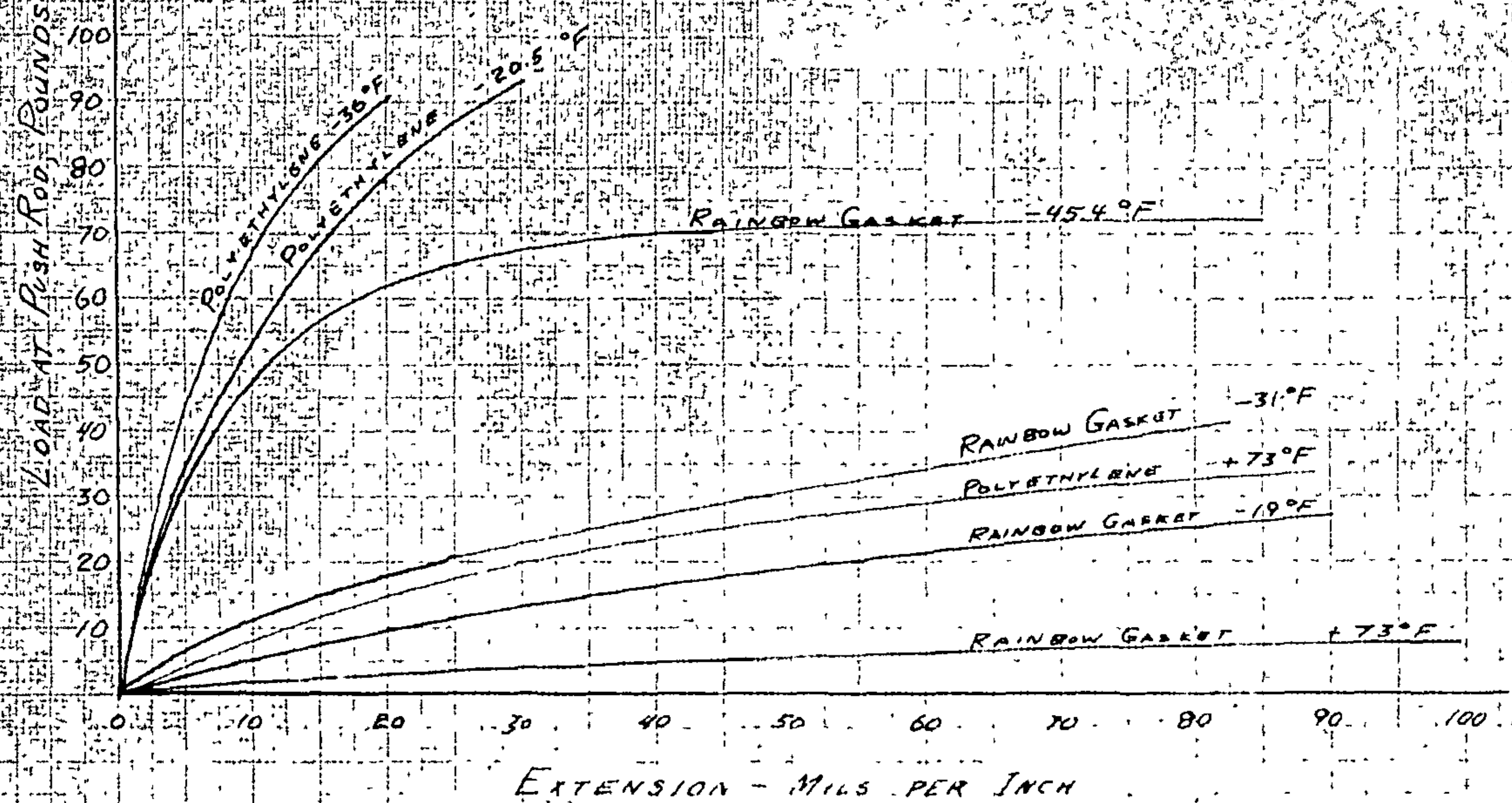
Time: 0.1 second

Note: All the crack lines were too fine to mark with talc making it difficult to ascertain position of first crack.

The extensometer results are shown in Figure 1. The room temperature values are derived from the Baldwin-Southwark values. It can easily be seen that the force required to stretch the polyethylene is much greater than that for the Rainbow gasket material at the same temperature. The force at the push rod may be multiplied by 1.77 to

Figure 1

Force Required to Stretch Polyethylene and Rainbow Gasket Strain Sheet Materials
(Specimens 1/16 inch thick and 1-inch wide)
(Multiply force at push rod by 1.77 to find actual force on specimen)



get the actual force on the one-inch wide specimen. The force required to extend the strain sheets at lower temperatures is shown to be sufficient to cause appreciable compression of the spring at the end of the push rod. This would tend to give a different rate of loading for different strain sheets.

The Durometer type A and D hardness values were found to be as follows:

	Shore Durometer Hardness (+81° F.)		Shore Durometer Hardness (-30° F.)	
Strain Sheet Material	Type A	Type D	Type A	Type D
U. S. Rubber Co. Rainbow gasket	87	37	over 100	70
Polyethylene	over 100	46	over 100	55

CONCLUSIONS

The following conclusions may be drawn while bearing in mind the hazard of generalizing from the meager data available.

It has been shown that the assumption that the spring at the lever end of the push rod does not compress during the extension of the strain sheets is questionable for at the lower temperatures where the stiffness of the strain sheet becomes appreciable the spring does compress significantly. This would tend to change the rate of loading and in some cases may have actually cut down the total extension which produced the cracks observed.

The thickness of the asphalt coating is important since the apparent extensibility passes through a minimum somewhere in the neighborhood of 10 mils. This may be due to the combination of surface forces and effect of the coating on the stiffness of the strain sheet.

The polyethylene is not sufficiently extensible at low temperatures. It tends to break at the middle range of extension. A faster rate of loading or a greater extension would undoubtedly increase the tendency for breakage. A search for more suitable strain sheet material is indicated.

The higher modulus materials will probably require some redesign of the tester. The following points might be considered:

1. Provision for a greater reserve of energy--such as a flywheel since it has been found that the present drive tends to stall when using a high modulus material as a strain sheet.

2. A stronger clamp at the zero adjustment is apparently needed as it was difficult to prevent slippage of the adjustable bar with the small cam.

3. The clamps for holding the specimens will probably need redesigning to withstand the high clamping pressures needed with the harder strain sheets.

4. The timing adjustment is a source of annoyance since it is difficult to adjust without danger of knocking off the locking pin on the cam.

5. The spring at the end of the push rod needs to be much stronger to prevent it from affecting the rate of loading significantly. There is some question as to whether this might not best be eliminated and some other technique be used to prevent overshooting the extension desired.

fv/mc

PROJECT REPORT FORM

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PROJECT NO. 1220-10-1
COOPERATOR Institute
REPORT NO. 2
DATE January 28, 1949
NOTE BOOK 659
PAGE 105 TO 138
SIGNED John M. Dowd
John M. Dowd

EXTENSIBILITY TESTER

I. Evaluation of Strain Sheets

II. Operating Characteristics of the Cold Box

III. Investigation of Film Thickness as a Factor in Extensibility

This report concerns principally evaluation of strain sheet materials. A little work was also done on the operating characteristics of the cold box, and a start was made on discovering the effect of film thickness on extensibility of asphalts.

PART I

EVALUATION OF STRAIN SHEETS

INTRODUCTION

Previous work in calibrating the extensibility tester has shown irregularities in the extensibility curve of strain sheets coated with asphalt. These irregularities did not appear when sheets were tested without asphalt coatings, and the irregularities were less for the stronger sheets. From this evidence and theoretical considerations, it was suggested that a strain sheet having a greater modulus of elasticity would give smoother and more consistent curves.

Several strain sheet materials were, therefore, evaluated for modulus of elasticity at various temperatures and percentages of extension. These materials were also evaluated for percentage of extension before failure at various temperatures and rates of loading, and for adhesion of asphalt.

The following materials were tested:

Material	Thickness	Supplied by	Supplier's Identification	Institute Identification
Neoprene	.0625"	Fabrics Div. Du Pont	Fairprene H-5550-FB	659-105-1
Perbunan rubber	.056"	Acadia Synthetics Products	PB-165-40-F	659-105-2
Polyethylene	.002"			659-105-3
Polyethylene	.060"	Bakelite Corp.	DS-3462 NAT	659-133-1
Vinylite Plastisol	.045"	Made up at Institute		659-110-1
Rainbow gasket material	.625"	Obtained locally		659-110-2
Buna rubber	.125"	U.S. Rubber Co.	993-41061 3#	659-112-1

METHODS OF TESTING

1. Modulus of Elasticity

Samples 1" wide and 7.44" long (6.94" between clamps) were cut and conditioned in the cold box at the testing temperature for at least 24 hours. The strip was placed in the clamps with the bare hands, and sample allowed to remain at least 15 minutes to attain the temperature of the box after handling. Clamps were closed and slack taken up by adjusting the bar on which the large clamp is mounted. A small spring scale, previously calibrated, was hooked over one of the three pins on the swinging bar carrying the small clamp. Force was gradually applied to the scale until the swinging bar touched the stop. This operation took about 10 to 15 seconds from the time force was first applied until the full extension was obtained. Force necessary to cause this extension is noted and recorded. The length of the lever arm from the pivot to the strip and from the pivot to the point of applied force is known and the observed force can thus be translated into force on the strip. The distance the strip is stretched is constant and known. The length, width, and thickness of the strip can be measured. From this information the modulus of elasticity is calculated.

2. Per cent Extension before Failure

At first, regular trapezoidal strain sheets were extended in each of the three ranges at various speeds and temperatures. This method was unsatisfactory for the following reasons:

a. Does not provide a wide enough range of extensions.

b. With some materials the machine will not handle a full-size strain sheet.

c. Speed of extension is somewhat in doubt when machine is heavily loaded.

d. Maximum per cent extension of the trapezoidal strain sheet is somewhat in doubt.

This method was therefore abandoned in favor of a method in which rectangular strips of three different lengths could be stretched at each of the three ranges. This gives a total of 9 different degrees of extension which, because of the rectangular shape of the strips, can be calculated easily and without resorting to assumptions regarding deviation from Hooke's law which are necessary with the trapezoid form. It is also possible to use strips as narrow as is necessary to prevent slipping in the clamps, stalling the machine, and possible slower extension than the calculated speed because of overloading the machine.

The device consists essentially of a metal bar with a pin near one end and three holes at various distances from the other end. The holes fit over the pin which normally holds the large clamp. The large clamp is then fitted on the pin at the other end of the bar. The distance between clamps can thus be set at three different distances.

3. Adhesion of Asphalt to Strain Sheets

In the first method, later abandoned, asphalt was spread on strain sheet materials with a spatula. The asphalt was at 302° F. and the strain sheets at room temperature. After the asphalt had cooled to room temperature attempts were made to scrape or pick the asphalt from the base material.

In the second method Kendall Refining Company asphalt Kendex 2060 (a hard, brittle asphalt) heated to 275° F. was spread 4 mils thick on strain sheet material. One set of samples was spread with the strain sheet material at room temperature. A second set was prepared in the same manner except that the strain sheet surface was heated for about 30 seconds by means of two 150 watt heat lamps positioned about 8 inches from the surface of the strain sheet.

Samples were conditioned in the cold box for several days at about -10° F. Sheets were then bent rapidly through a known arc by means of a cone and roller affair in which the sheet is bent around the cone by means of the roller. Degree of flaking off was noted. Since this did not provide a sufficiently severe test of the better materials, the samples were further subjected to severe flexing and stretching by hand.

DATA OBTAINED

Because Rainbow gasket material was the material which gave the best curves in the calibration work, it has been selected as a base point with which to compare the other materials. The ideal material would have a modulus of elasticity greater than Rainbow, at least as extensible as Rainbow or slightly more extensible, and adhesion to asphalt comparable to Rainbow although slightly less could be tolerated.

1. Vinylite plastisol--This material consisted of about 40% Vinylite VYNW and 60% Dioctyl Phthalate.

Modulus of elasticity was found to be much lower than materials already tried (Neoprene and Rainbow) and no further work was done with this material.

2. Dow silicone--Adhesion of asphalt to this material was very poor. Because of this fact and its high cost no further work was done with this material.

3. Neoprene--This material has a lower modulus of elasticity than Rainbow. It has very good extensibility as attested by the fact that no signs of failure could be detected even when extended 20.5% at -30° F. at the highest speed. Modulus of elasticity plotted against temperature seems to give essentially a straight line. Adhesion of asphalt is excellent.

4. Acadia Synthetic Products Company perbunan rubber--Modulus of elasticity even lower than Neoprene. No signs of failure when extended 20.5% at -30° F. and highest speed. When an attempt was made to plot modulus against temperature, the points were found to be badly scattered. Because the strength was so low, it was difficult to get the same initial tension on the strip in each modulus of elasticity test. It may be that this is the reason for the badly scattered results. As near as can be determined from the scattered results, however, this material seems to exhibit an essentially straight line relationship between modulus and temperature. Adhesion to asphalt was excellent.

5. U.S. Rubber Company Buna Rubber--Modulus of elasticity was very low, lower than Acadia. No evidence of failure at greatest extension, lowest temperature and highest speed. Adhesion excellent.

6. Rainbow gasket material--Modulus of elasticity more than twice as great as Neoprene which is the strongest of those mentioned above.

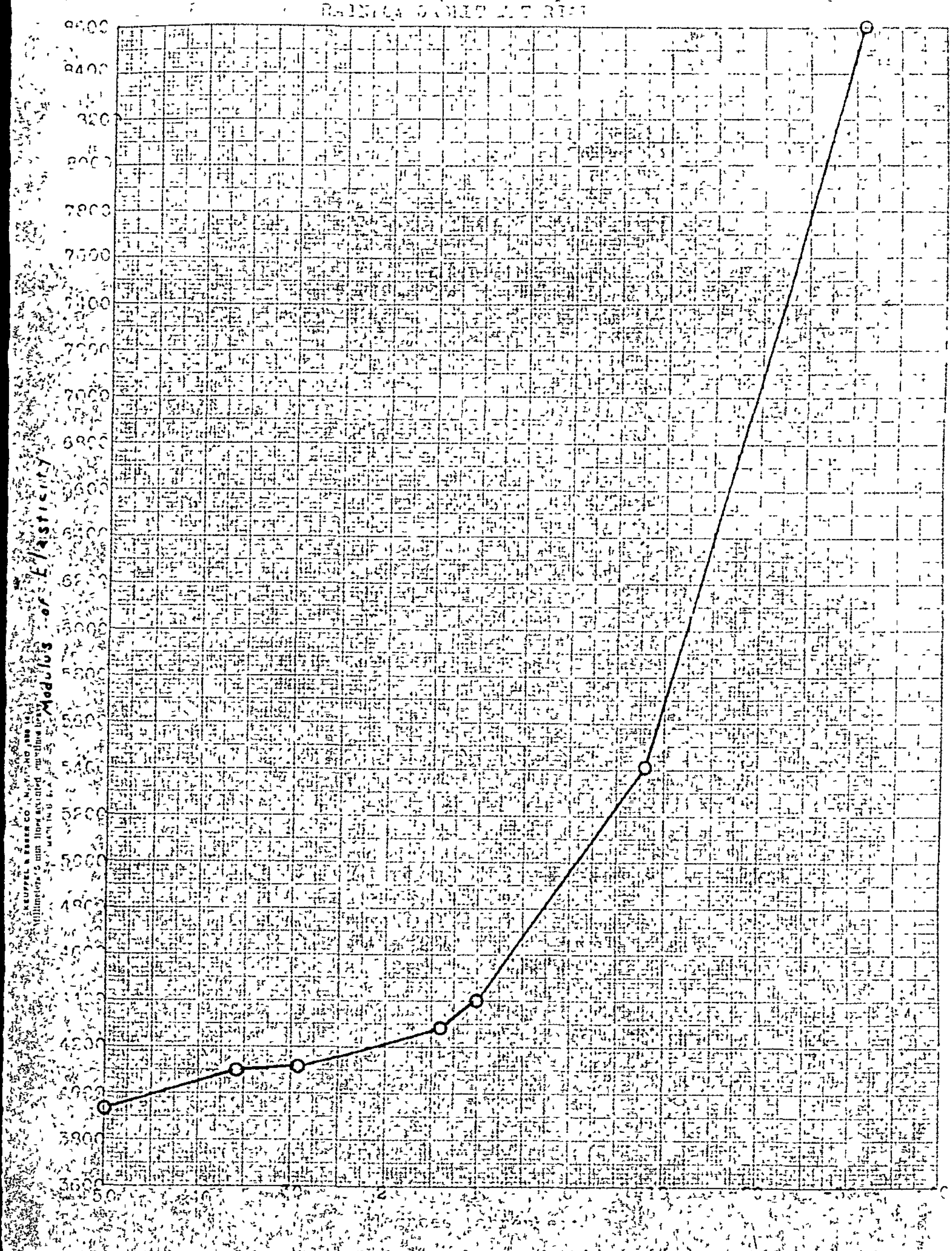
In previous work this material broke occasionally in high range at the lower temperatures. This was confirmed in the present work. However, when using the new method for testing extensibility, the material did not break completely even at 20.5% extension, -27.4° F. and highest speed. It did, however, show surface cracks as low as 12.5% extension at the above speed and temperature. Adhesion to asphalt excellent.

Rainbow did not exhibit a straight line relationship between temperature and modulus of elasticity as the other materials did. At about +10° F. the slope of the line suddenly increased sharply. See graph 1.

7. Polyethylene--Modulus of elasticity very high (7 or 8 times as great as Rainbow). Temperature-modulus of elasticity relationship is a straight line (see graph 2). Adhesion of asphalt is poorer than Rainbow but still good.

In the extensibility tests strips 0.25" wide were used instead of the standard one-inch strips because the machine would stall with one-inch or even 1/2-inch strips. Rather complete tests were run to discover the critical temperature at various speeds and per cent extension. By critical temperature is meant the lowest temperature at which the strip did not fail. Just below such temperature failure occurs at the given speed and per cent extension. These tests indicate that the material will not fail at -30° F., and highest speed at 8.6% extension which is the maximum extension in high range of the

GRAPH I



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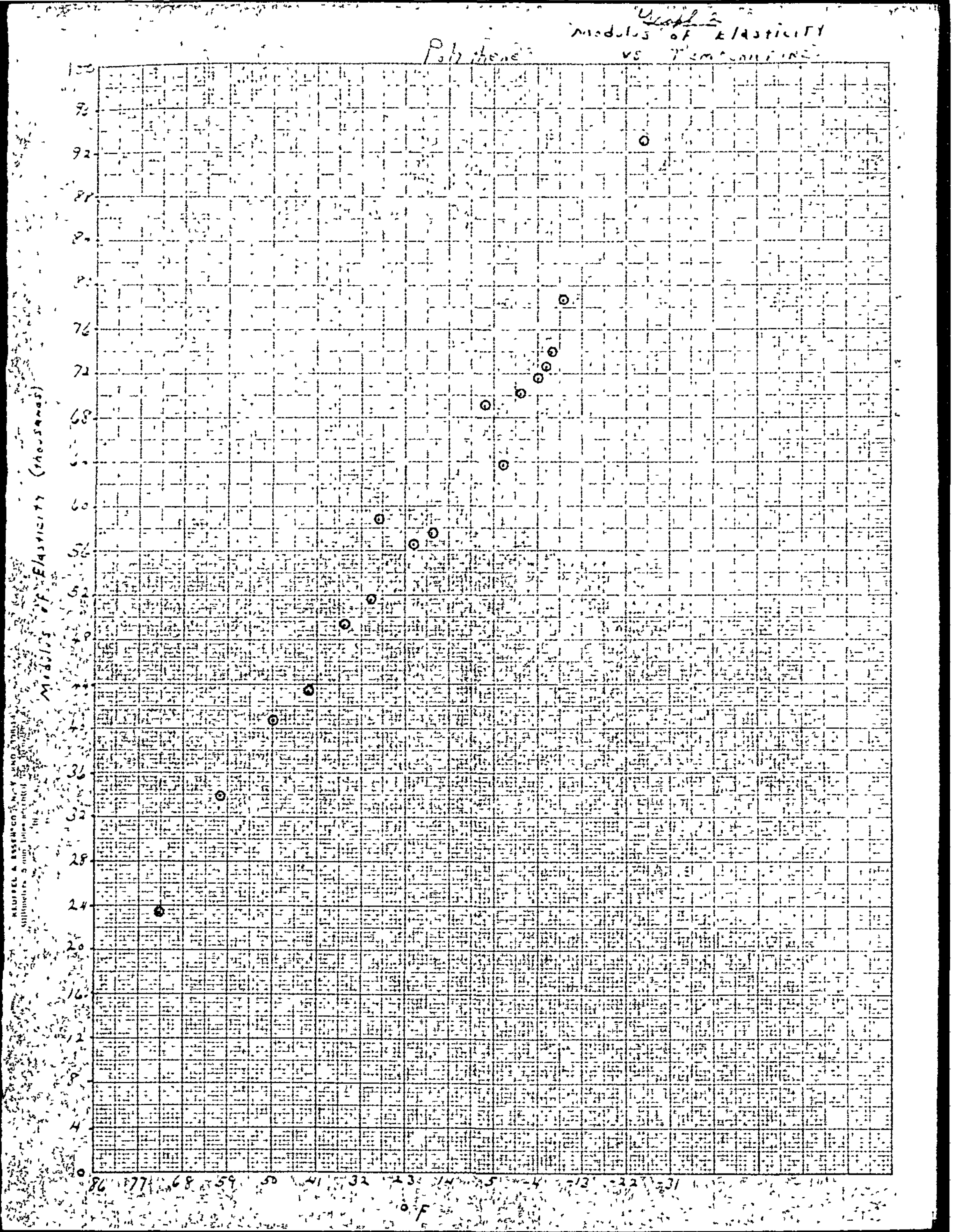
3600
Modulus of Elasticity



Graph 2
Modulus of Elasticity vs Temperature
Polythene
Modulus of Elasticity (thousands)
°F

trapezoidal strain sheet according to the calibration work previously done. By this evidence alone, it would appear that this material is sufficiently extensible to be used at the extremes of the machine and cold box. The contradictory results with Rainbow in trapezoidal form and rectangular form, however, cast serious doubts on such conclusions. A trapezoid strain sheet of Rainbow could be broken occasionally at the highest speed and lowest temperature in high range (8.7% extension according to the calibration work) but in the new method of testing rectangular strips the first signs of failure appear at 12.5% extension.

The polyethylene will stand a 12.5% extension at highest speed as low as -15° F. In view of the results obtained with Rainbow this is probably the lowest usable temperature at high range and high speed. If the speed of extension is decreased, the critical temperature is considerably lower. For instance, polyethylene can be extended 12.5% at least as low as -24° F. and perhaps lower if the extension speed is reduced to about 1/3 of the highest speed. Table I summarizes the critical temperatures found for various speeds and percentages of extension.

TABLE I

LOWEST USABLE TEMPERATURE AT GIVEN SPEED
AND PER CENT EXTENSION

Per cent			Camshaft speed, (R.P.M.)						
Extension	1900	1060	620	545	311	180	158	90	45
20.5	+ 9	+ 7.5	- 8	-12.5					
14.0	- 7	-14	-24						
12.5	-15								
10	-24	-28							-30
8.6	-30								
6.9									
6.6									
4.0									
3.2									

Temperatures are in degrees Fahrenheit.
Material tested is Polytehylene.

8. General Data--The relationship between percentage extension and modulus of elasticity at constant temperature was investigated for the five materials under consideration (Rainbow, Neoprene, Polyethylene, U.S. Rubber Company, and Acadia Synthetic Products rubber).

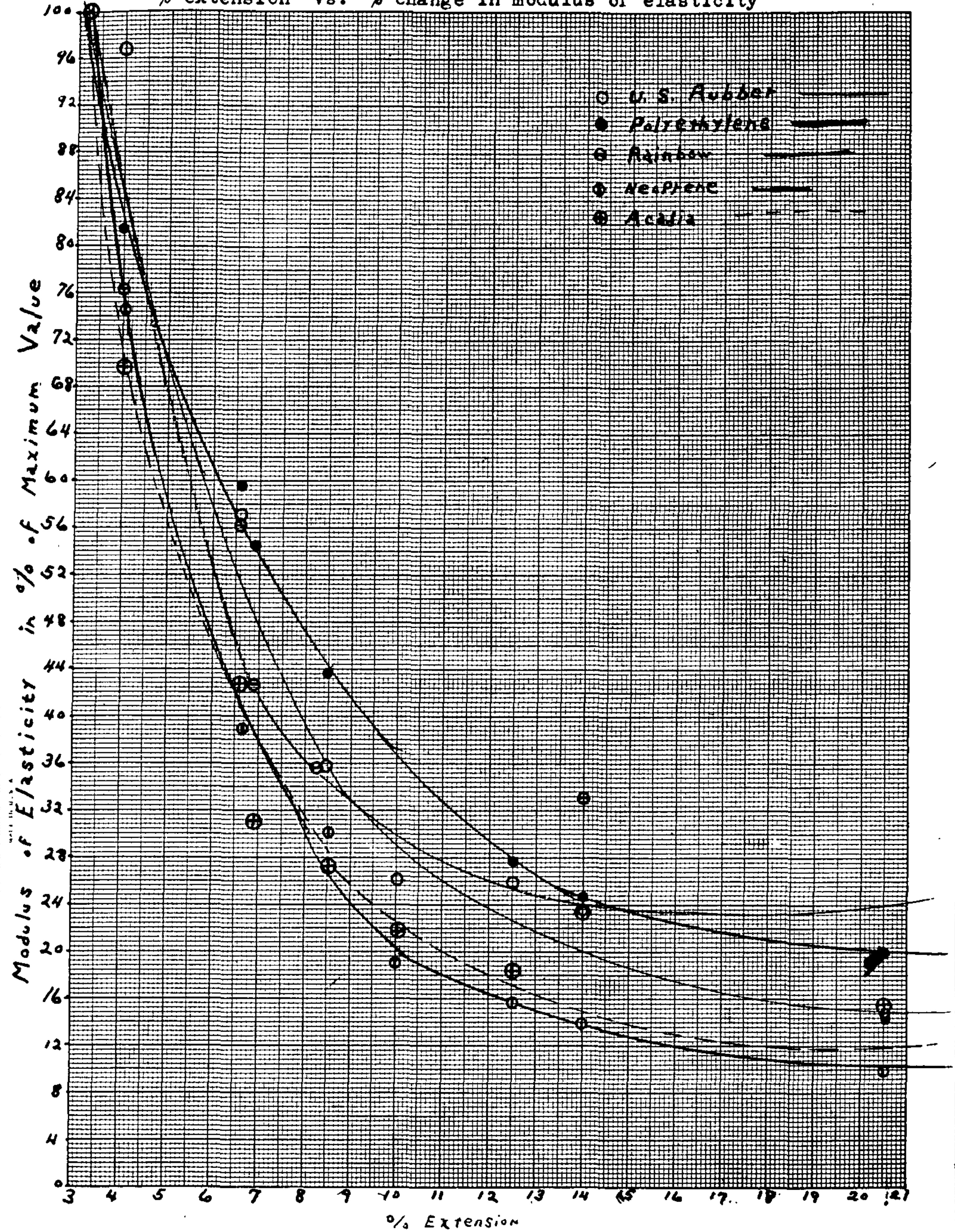
When per cent extension was plotted against per cent of modulus of elasticity (modulus at 3.1% extension considered 100%), the curves were all of the same general shape (see graph III). The curve for polyethylene lies above the curves for all other materials. That is, it follows Hooke's law more closely. In the calibration work, using Neoprene, it was assumed that this relationship would be a straight line relationship up to 8.7%. While this is very nearly true up to about 8 or 9 per cent (especially for Neoprene) it is not true beyond 9%. With polyethylene the curve departs considerably from a straight line even below 9%.

SUMMARY OF RESULTS AND CONCLUSIONS

Of the materials tested only polyethylene shows any advantage over the materials previously used (Neoprene and Rainbow). Polyethylene is very good from the point of view of modulus of elasticity but it is probably not extensible enough to be used over the full range of the instrument. If the extensibility could be increased even a little it would be usable over the full range.

The U.S. Rubber Company and Acadia Synthetic Products samples are very good for extensibility but modulus of elasticity would have to be greatly increased before they would be useful.

% extension Vs. % change in modulus of elasticity



I can find no satisfactory explanation of the fact that a trapezoidal strain sheet of Rainbow broke occasionally at a strain assumed to be 8.7% but a rectangular strip only exhibited surface cracks at 12.5% and did not completely break even at 20.5%. There are several possibilities:

1. The trapezoid sheets were used over and over again and may have broken for this reason. The rectangular strips were stretched only once or twice.

2. The Rainbow material seems to vary considerably from batch to batch. For this reason a rectangular strip was cut from one of the old strain sheets, thought to be from the same batch as the sheets that had broken. This strip did not break at any lower extension than the strips cut from a fresh sheet of Rainbow.

3. The assumption of 8.7% extension for the trapezoidal sheet might be incorrect. This figure is based on data collected in calibration work with Neoprene. Examination of the per cent extension vs. per cent change in modulus of elasticity curves of the two materials seems to indicate that data obtained from Neoprene should apply fairly well to Rainbow and, furthermore, the expected deviation should be in the direction of a lesser extension of the Rainbow rather than a greater extension.

These curves, however, were plotted at a temperature considerably above that at which the Rainbow broke. The temperature vs. modulus of elasticity curve of Rainbow as well as the general appearance and feel of the material indicates that at a temperature of about 10° to 0° F. the material undergoes a marked change. It may be that at the breaking temperature the extension vs. modulus curve would be entirely different.

SUGGESTIONS FOR FURTHER WORK

Some new samples have been received from Goodyear. These will be tested for modulus of elasticity.

The machine will not handle full size strain sheets of polyethylene. The machine would have to be modified to use it. Extensive tests for adhesion of waxes and various asphalts should be made on polyethylene, of course, before such modification is undertaken, since the polyethylene might prove unsuitable on the point of adhesion.

PART II

OPERATING CHARACTERISTICS OF THE COLD BOX

INTRODUCTION

An attempt was made to discover the lowest practicable temperature that could be maintained, the lowest temperature attainable, the variation of temperature in the box with different controls, and cycling characteristics of the box.

METHODS OF TESTING

The cycling time was recorded by means of a recording voltmeter placed in the compressor motor circuit.

The temperature variations were observed by means of a thermocouple hanging free in the middle of the box approximately on a horizontal line with the top of the extensibility tester. The EMF of the thermocouple was observed by means of a sensitive galvanometer. A Dewar flask containing water at room temperature or ice and water was used as the hot junction. A mercury thermometer was inserted in the flask to check the stability of the hot junction temperature and furnish information for correcting the galvanometer readings to compensate for any variations in this temperature.

An attempt was made to record temperature fluctuations with a large gas pressure-type recording thermometer, but the heat capacity of the thermometer caused a lag so great as to completely mask any temperature fluctuations in the box.

DATA OBTAINED

The lowest temperature that can be attained varies somewhat, of course, depending on the temperature in the room and the efficiency of the compressor at the moment. It was found, however, that a temperature lower than about -30° F. cannot be counted on. If the box is to be opened frequently, as it must if work is being done with the extensibility tester, a temperature of less than about -22° F. cannot easily be maintained.

The pressure-type control used maintains the temperature within a narrower range than the thermal type control used under the conditions of the test, i.e., no forced circulation in the box. The temperature variation with either type of control does not seem to vary with the temperature maintained in the box. This information is listed in Table II.

SUGGESTIONS FOR FURTHER WORK

Three temperature controls are being placed on the box. An investigation could be undertaken to discover how nearly the temperature of the box will return to a previously attained temperature when the control is not disturbed. That is, the control is cut out of the circuit without disturbing the setting, a second control is cut in to attain a different temperature, then the first control is put back in the circuit while the second is cut out. If the box returns to the original temperature under such conditions, it would be advantageous to select three standard temperatures, set each of the controls at one of these temperatures, and do all testing at one of the three standard temperatures.

TABLE II

TEMPERATURE VARIATION AND CYCLING TIME OF COLD BOX

Median Temperature, °F.		Temperature Variation, min. to max. (°F.)	Cycling Time, min. On	Off
		Pressure Type Control		
64.5		7.63	5	13
		6.09	5	13
		6.79	5	13
	Av.	6.34 ± 0.53	5	13
17.6		7.74	2	8
		7.92	2	9
		5.58	2	9
		6.48	2.5	10
		6.84	2	9
		6.12	2	9
	Av.	6.78 ± 0.70	2	9
		Thermal Type Control		
32		10.98	10.75	81
		9.90	9.0	74
		9.18	10.5	81
	Av.	10.02 ± 0.64	10.1	80
14		8.64	16.75	18
		6.84	15	19
		11.88	16.67	20
	Av.	9.12 ± 1.84	16	19

PART III

INVESTIGATION OF FILM THICKNESS AS A FACTOR IN EXTENSIBILITY OF ASPHALTS

INTRODUCTION

Data collected in previous work with the extensibility test indicate that asphalts may be more extensible in thin films than in thick films. It has been suggested that this apparent increase in extensibility in thinner films may be due to the difficulty of seeing the very fine cracks in the thin film. This would lead to identifying another crack farther from the broad end as the last crack toward the broad end. Special care will be taken in these experiments to avoid such errors and to note if the cracks in the thin films are very much harder to distinguish than the cracks in the thicker films.

METHODS OF TESTING

All of the strain sheets for these tests were cut from the same sheet of Rainbow gasket material to avoid errors due to variations in the strain sheet.

The Martinson coater was used to coat the asphalt on the strain sheets. A panel of photographic plate glass was placed on the table of the coater to furnish a more nearly flat surface than is furnished by the table itself. Over this was fastened a sheet of paper with two parallel slits in it at such a distance apart that when a strain sheet is placed on the paper the ends of the strain sheet will slip through the slits and lie under the paper for about 1/2" on each end of the strain sheet, thus masking the ends from the asphalt. The sides were masked for about 1/4" along the edge with Scotch tape.

The thickness of coating to be applied was adjusted by measuring from the paper to the blade with a feeler gauge allowing 62.5 mils for the thickness of the strain sheet. The coating thickness determined by this method is called "nominal thickness." The actual thickness was later measured with a dial micrometer by measuring the thickness of the strain sheet and asphalt film and subtracting from this figure the thickness of the strain sheet alone as measured at the uncoated ends of the sheet. The micrometer is divided into divisions of .001" and can easily be read to ± .00025".

The asphalt was kept in an oven maintained between 340 and 400° F. The strain sheets were preheated for about 10 to 15 seconds by means of two 150 watt heat lamps positioned about 8" above the surface of the sheet. Six sheets were coated at each thickness, nominally, 1, 2, 5, 10, 20, and 39.5 mils. The asphalt used was Kendex 2230 from Kendall Refining Company.

The samples were extended in high range at a temperature of -11.5° F. ± 1.5 at a drive shaft speed of 545 r.p.m. (extension time of 0.055 seconds).

The samples, while extended, were dusted lightly with talc and the excess brushed off with a camel hair brush. The sheet was inspected carefully with the aid of a flashlight to detect the last crack toward the broad end of the sheet. It was found that cracks were harder to see on the thin films, but not so difficult as to make it likely that a crack would be overlooked on careful inspection.

DATA OBTAINED

Extensibility at the various thicknesses is tabulated in Table III. Because of the wide variation among samples of the same nominal thickness,

TABLE III

EXTENSIBILITY OF KENDEX 2230 AT VARIOUS THICKNESSES
(Average of 6 trials)

Speed: 545 r.p.m.

Range: High

Temp.: -11.5° F. ± 1.5° F.

Strain sheet material: Rainbow

Nominal Coating Thickness, mils	Distance from Large Clamp to First Crack, cm. Minimum	Maximum	Average
1	5.9	9.5	8.1 ± 1.2
2	3.5	8.5	5.85 ± 1.25
5	2.2	7.9	4.2 ± 1.47
10	2.9	5.7	4.57 ± 0.88
20	1.0	7.5	3.1 ± 2.1
39.5	3.1	7.8	5.2 ± 1.3

measurements of the thickness were taken as outlined above. These measurements indicate a very great discrepancy between nominal and actual thickness, a large variation in thickness from point to point of the same sample, and a considerable variation in average thickness from sample to sample of the same nominal thickness. This wide scatter is summarized in Table IV.

SUMMARY OF RESULTS AND CONCLUSIONS

In attempting to account for the variations in thickness and the wide departure from the calculated thickness based on the setting of the Martinson coater, several possibilities suggest themselves.

TABLE IV

THICKNESS OF ASPHALT FILMS TESTED FOR EXTENSIBILITY
(measured in mils)

Sample	Nominal Thickness	Min.	Max.	Av.	Average Deviation	Group Average
1	1	1.5	2.5	2.2	.36	
2		2.5	3.5	2.9	.25	
3		2.5	3.25	2.95	.32	
4		2.0	3.0	2.4	.10	
5		1.0	2.0	1.5	.46	
6		1.0	2.25	1.8	.18	2.3
1	2	2.0	2.25	2.04	.21	
2		2.5	3.0	2.8	.24	
3		1.0	2.0	1.75	.38	
4		2.0	2.5	2.3	.24	
5		2.0	2.5	2.2	.24	
6		2.0	2.25	2.19	.09	2.21
1	5	3.0	4.0	3.33	.33	
2		2.25	3.0	2.54	.22	
3		1.5	3.5	2.5	.75	
4		2.5	3.0	2.6	.16	
5		2.5	4.0	2.6	.62	
6		3.0	3.5	3.17	.17	2.8
	10					11.0
1	20	17.25	24.5	20.79	1.38	
2		11.0	20.0	15.2	2.24	
3		20.5	24.5	22.4	1.25	
4		3.5	12.5	5.6	2.76	
5		3.0	6.0	4.3	.84	
6		17.0	23.0	20.3	1.92	14.8
1	39.5	8	24.0	15.3	4.43	
2		16	29.0	24.25	4.75	
3		10	24.0	18.6	4.88	18.4

1. The Scotch tape used along the edges of the strain sheet to mask it from the asphalt would hold the blade at a certain minimum distance above the sheet. This could account for the fact that the 1, 2, and 5 mils settings gave about the same thickness of coating.

2. The variation from point to point on the same sheet and the variation in average thickness from sheet to sheet might be due to the fact that the sheets did not lie flat on the coater table.

3. Some variation might be due to failure to control the temperature of the asphalt closely enough.

SUGGESTIONS FOR FURTHER WORK

Care must be taken to control the film thickness within much narrower limits and 30 or more samples of each film thickness should be run in order that statistical methods could be applied.

There are several changes in procedure that might help to obtain more uniform coatings.

1. Stick the strain sheets flat on the coater table by means of sheets of double-faced Scotch tape.

2. Omit the masking tape along the edges of the strain sheet when coating films under 10 mils in thickness.

3. Control the temperature of the asphalt within $\pm$ 5° F.

4. Measure the thickness of each strain sheet individually and adjust the coater accordingly.

jmd/mlh

PROJECT REPORT FORM

Copies to: Files
Mr. Steele
Dr. Howells
Dr. Rawcliffe
Mr. Rae

PROJECT NO. 1220-10-1
COOPERATOR Institute
REPORT NO. 1
DATE February 15, 1947
NOTE BOOK
PAGE
SIGNED Robert D. Rae

Robert D. Rae

MODIFICATION OF THE EXTENSIBILITY TESTER

Operational experience with the Extensibility Tester indicated several modifications should be made before continuing further tests. Figure 1 shows the instrument before modification. In this instrument the strain sheet is elongated by movement of the small clamp secured to the lever arm on the near side of the base plate. The lever is moved by action of a wedge shaped cam driven by a falling weight. This weight can be seen in the raised position over the square shank of the cam.

The tester was modified as follows:

1. An electric motor drive replaced the falling weight as a source of power. Variable speed was provided to permit investigation of the rate of extension.

2. The instrument was located in the cold box near the top opening to make it easier to manipulate the instrument.

3. A double paned window with hand holes was fitted to the top opening of the cold box to shield the tester from warm air.

In providing the motor drive, the instrument was used as before with the exception of removing the wedge cam and weight. The motor rotates a circular cam through a suitable speed reduction. The motion of the cam is transmitted by a push rod to the lever on which the small clamp is mounted. For convenience of operation, the motor speed change unit and cam are mounted outside the refrigeration box with the push rod extending through to the tester inside.

Figure 2 is a photograph of the modified instrument in the refrigerator box looking down upon the tester. Figure 3 is a photograph of the power unit at the outside of the refrigerator box.

The following discussion is provided to explain the working of the machine and reasons for the changes made.

MECHANICAL DRIVE

Cone V-belt pulleys were selected to provide the variation in speed. Cone pulleys were easy to obtain and assemble and could be done more easily than building a gear box and transmission. Two sets of pulleys were used. The pulleys have a small diameter of 2 inches and a large diameter of 5 inches. That provides a speed change of 6.25 to 1 for one set or 6.25 x 6.25 = 39 to 1 for a combination of two sets. Arbitrarily selecting 1/50 of a second as the fastest extension desired, then the slowest speed available would be 1/50 ÷ 39 or about 4/5 second. Pulleys from the motor to the first cone pulley shaft were selected to drive that shaft at 240 r.p.m. and thus obtain the final drive speeds as required.

The cam and push rod were designed to have as little inertia as possible to cause the least shock to the system on starting and stopping. A dog-clutch (H - Figure 3) keyed to turn with the final drive shaft (D) engages the cam by sliding horizontally along the shaft. The clutch is normally disengaged.

Upon release of lever (G), a coil spring behind clutch (H) drives it into engagement with the cam (J). If the lever (G) is activated before the teeth of the clutch have rotated to close on those of the cam, the cam is held in place by lever (K) until the clutch rotates to full engagement and positive drive results. The cam has a flat at the end of the lift to insure that the push rod stays at the extreme position. In turning, the cam pulls itself along the shaft due to threads on the far end of the cam hub. By the time the cam has rotated to accomplish the movement of the push rod, it has moved out of engagement with the clutch. The clutch is limited in its travel by adjustable screw (E). Thus disengaging the clutch is automatic. Lever (K) has a second purpose. That is to catch the cam when rotation is complete and prevent rebound.

The cam was designed to give the lift in one half revolution. The other half revolution could be used to start and stop the cam. The shape of the cam was determined by the equation $X = K\theta^2 = K^1t^2$, where θ is angle and t is time; thus uniform acceleration was imparted to the push rod.

A motion of 0.500 inch was required. The cam lift was made 0.550 inch. The excess 0.050 inch motion is taken up in the push rod at the end of the travel. The push rod has a follower wheel to ride the cam and a spring loaded button (C Figure 2) at the opposite end. The spring is of sufficient strength not to be compressed during the movement of the lever and extension of the rubber strain sheet but will yield to the force exerted when lever (A) hits stop (B). This arrangement was made to insure there would be no slack in the system and full movement could be obtained.

A connecting tube enclosing the push rod joins the power unit and extensibility tester. The tube is mounted firmly in rigid brackets at either end. Grooves in the tube and a mating ridge in the bracket insures the power unit and extensibility tester will remain a fixed distance apart. The tube has bushings in either end to guide the push rod. Both tube and rod are of stainless steel to avoid corrosion, due to condensation. In the interest of reducing inertial effects, the push rod is actually a tube.

When one extension is complete the motor is shut off, the clutch reset, and the cam turned by hand to the starting position. The unit is then ready for another test. The push rod and lever (A) being spring loaded follow the cam on the return.

CONVENIENCE OF OPERATION

In the original unit the weight tower extending above the platform made it necessary to set the tester in the bottom of the refrigerator box. Since the modified unit eliminated the weight tower, the unit was mounted on legs so as to be located a convenient distance below the top of the box. Not only does this make the tester more accessible, but it provides a better view of the clamp jaws, making it easier to position and clamp the strain sheet.

The clamp jaws were modified by changing the location of the clamp eccentric cam with respect to the closing lever. This provides a maximum jaw opening of 0.150 inch and a closure to 0.080 inch. Thus a new size of strain sheet can be accommodated (Strain sheet thickness 0.120 inch).

To permit use of thinner strain sheets as used before, a single steel shim 0.040 inch thick inserted under the clamp cam changes the maximum opening to 0.110 inch and minimum opening to 0.040. Thus a sheet 0.065 inch thick can be used.

DOUBLE PANED WINDOW

A one-inch angle iron frame mounted just below the top edge of the refrigerator box provides a ledge on which to set a window frame. The rectangular area of the window frame is divided into two sections, one covered with cloth having two slots for hand holes, the second and largest portion is a double paned sealed glass. The two panes are separated by 3/8 of an inch. The glass is sealed in place with asphalt. The air between the glass was replaced by dried air and the holes sealed. This construction has proved an adequate safeguard against frost on the window.

To further insure uniform temperatures within the refrigerator box, a small circulating fan is to be used to prevent air stratification.

The tester thus modified is again being calibrated.

rdr/svj

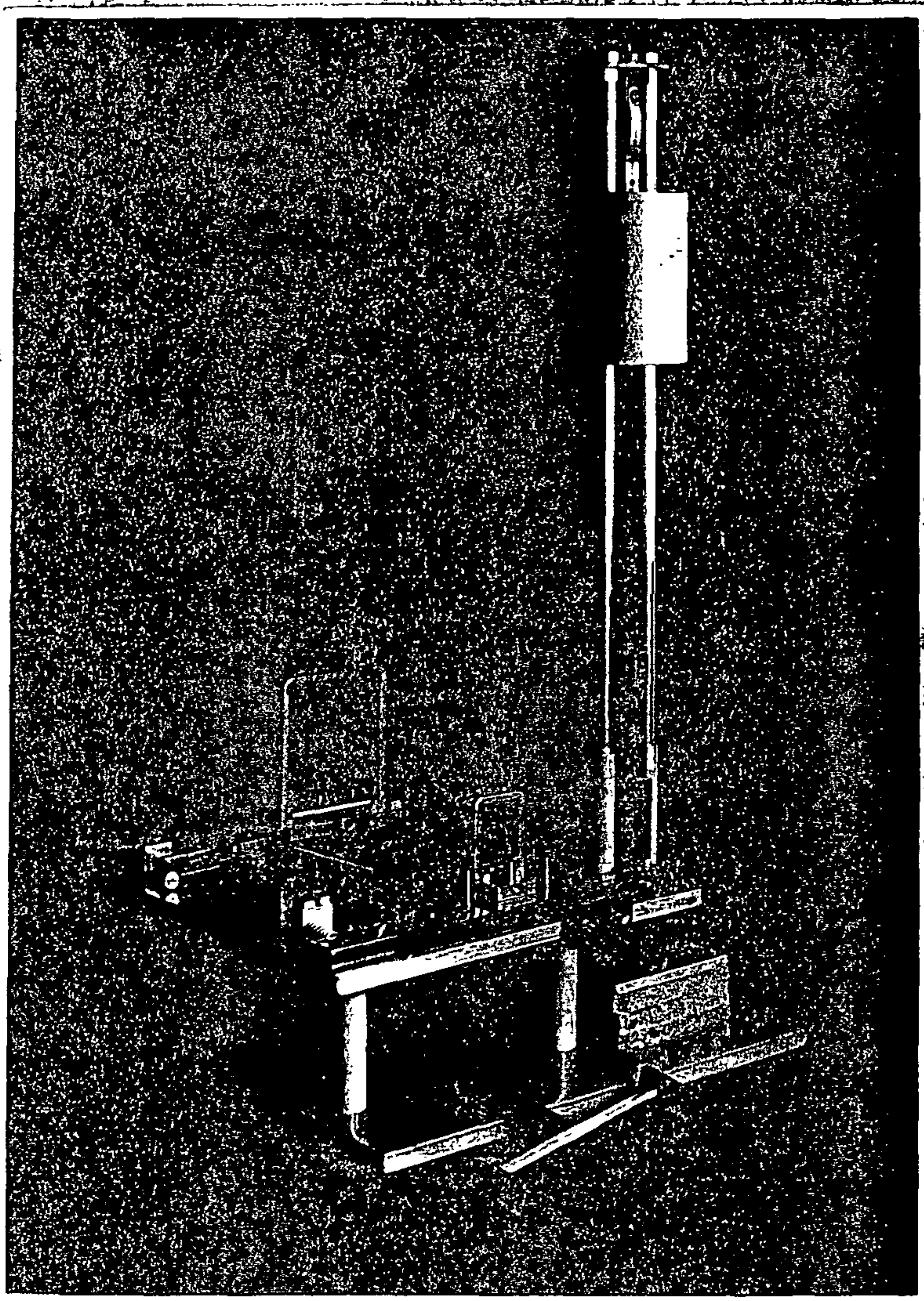


Figure I

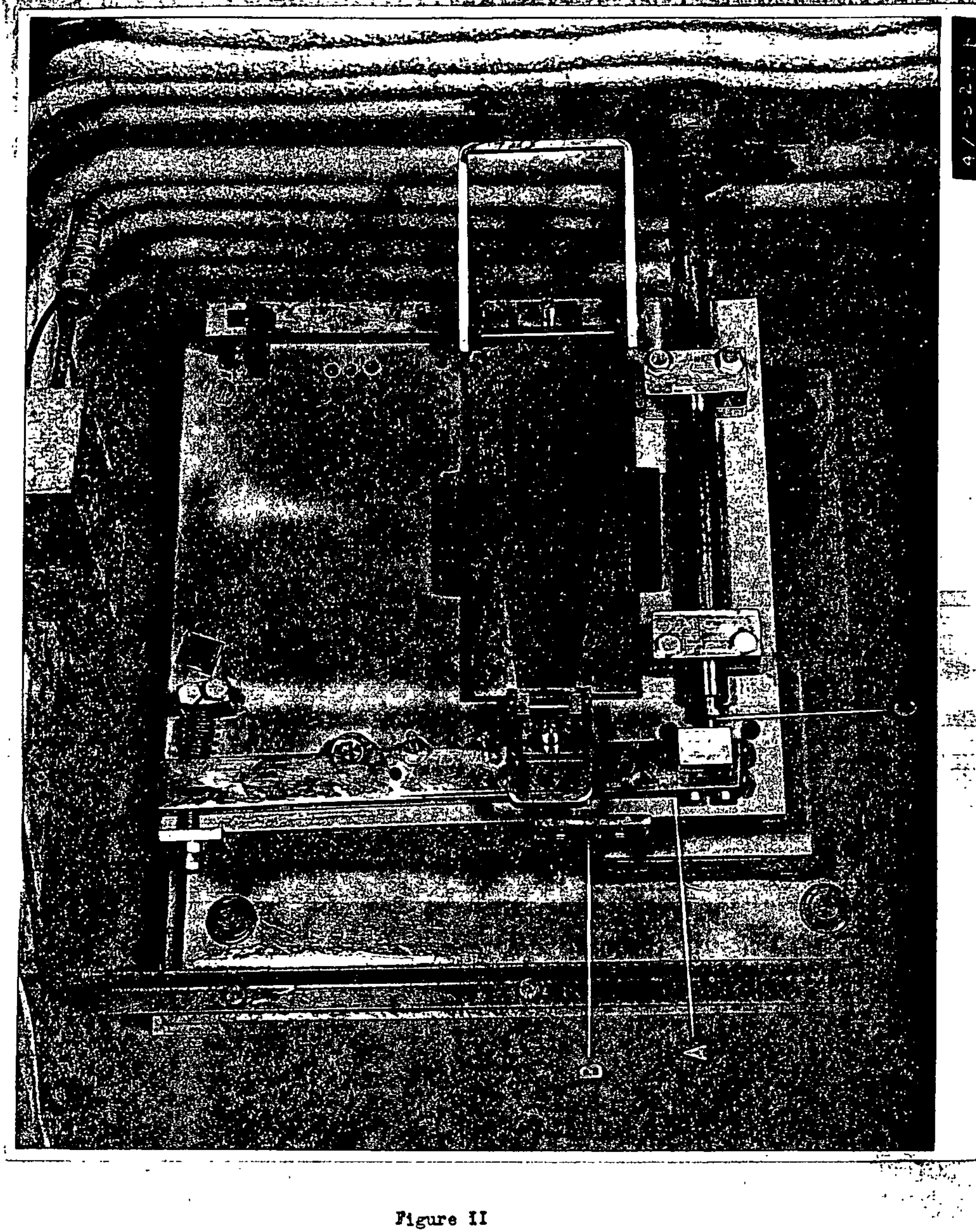


Figure II

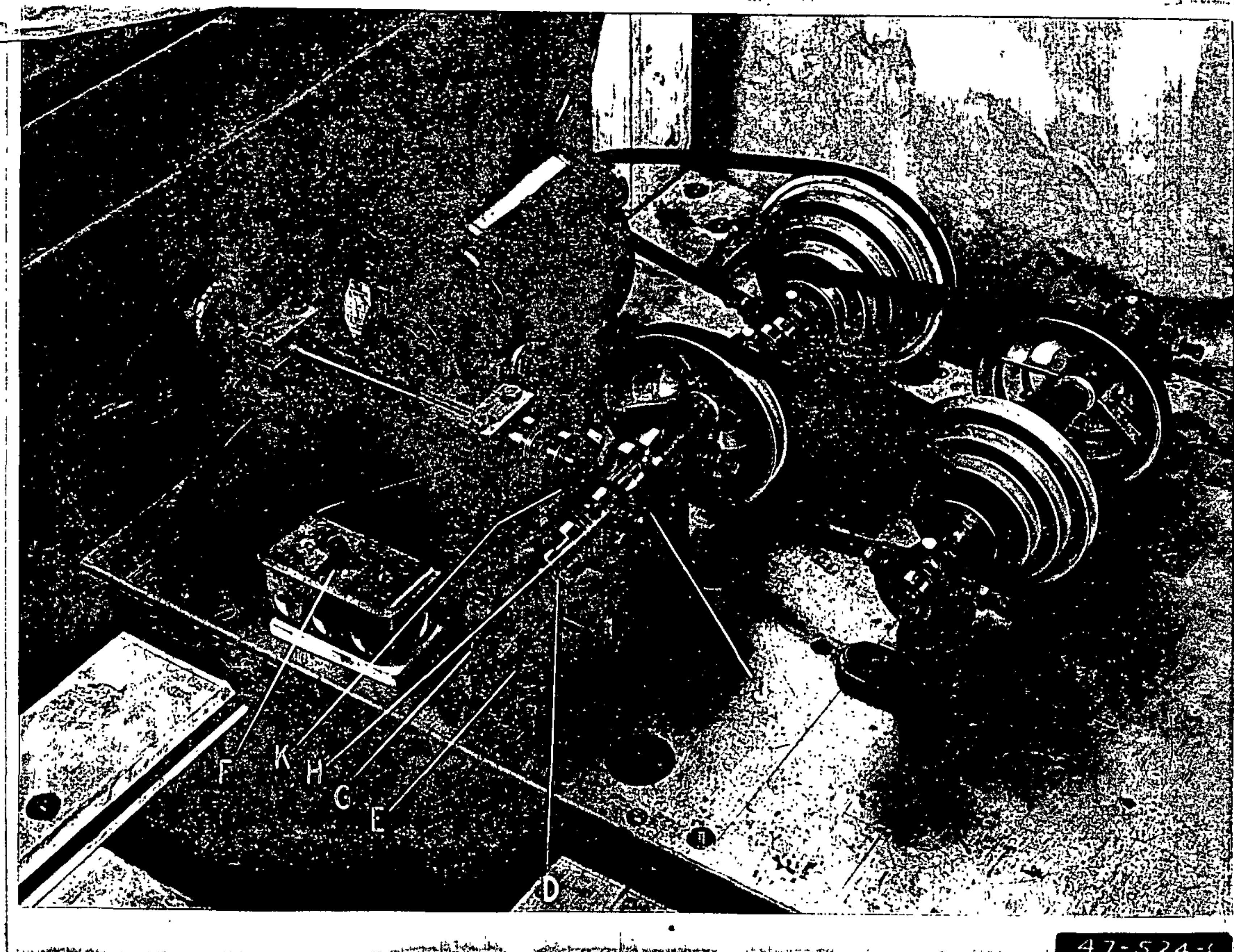


Figure III